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Method of separating particles in a fluid medium and an apparatus therefor

The present invention relates to a method of separating particles in a fluid medium having a density higher than that of the particles to be separated, whereby a mixture of the particles to be separated is fed to a separation chamber of a separation apparatus, and streams enriched in a particular type of particles are discharged from the separation chamber.

The use of a fluid medium for the separation of a mixture of particles in two or more fractions is generally known. When the particles have a specific density lower than that of the fluid medium, such a separation is not very easy. It is known in the art to use centrifugation in order to increase the effect of the difference in density between the types of particles. This technique is expensive and often results in an unsatisfactory separation.

The object of the present invention is to provide a method wherein mixtures comprising different types of particles can be separated adequately.

To this end, the method according to the present invention is characterized in that the mixture of particles is subjected to a treatment comprising the step of moving the fluid medium up and down relative to the mixture of particles, whereby a barrier is present above the particles for restraining the particles.

Surprisingly it has been found that moving a mixture of particles having a density lower than that of the fluid medium up and down relative to said fluid medium (also known as "jigging") may effect stratification to achieve a separation. Jigging has been known for decades but not for the separation of particles having a density lower than that of the surrounding fluid medium. The mixture may comprise, for example, cork or wood. It may also be a mixture derived from domestic refuse. The barrier present for restraining the particles may be the face of the fluid medium. A stream enriched in particles of a particular type comprise the fluid medium

and the particular particles. The separation according to the present invention will result in (at least) two streams: A first stream enriched in first particles having a density lower than that of the fluid, and a second stream enriched in second particles having a density lower than that of the fluid.

According to an important embodiment, the particles to be separated are plastic particles.

The separation of plastics is a very important application for which, indeed, currently a number of different techniques is available, but which all suffer from one or more important disadvantages. For example, it is known to separate particles electrostatically, (which method is very sensitive to the presence of humidity), measuring particles individually using infrared light, (which method is slow and expensive), performing a float-sink separation in a hydrocyclone or using water-air suspensions. The separation of plastics makes it possible to obtain higher grade plastics which can be used for the manufacture of new plastic products. In addition, the use of compatibilizers is substantially avoided or even unnecessary. This not only entails a savings in cost, but also the plastic product manufactured from the recycled material is of higher quality, and can be re-used more often.

According to an important embodiment, the plastic particles are polyolefines.

Using the method according to the present invention, a separation may be performed quickly and efficiently even with very similar plastics, such as polyethylene and polypropylene.

According to an important embodiment, the fluid medium is an aqueous medium, in particular water.

The use of aqueous media and in particular water, which are very cheap fluid media, does not result in contamination of the streams enriched in a particular type of particles and do not discharge volatile organic compounds (or just to a reduced extent). When using an aqueous medium such as water for the separation of plastics, care should be taken that the particles are well wetted by the fluid medium in or-

der to prevent adherence of air bubbles (which cause a false change in the density of the particle). This may be accomplished using friction-washing with the fluid medium or by adding low concentrations of surfactants. It is also possible to perform the method under elevated pressure (as a result of which any air bubbles present dissolve), or under reduced pressure (resulting in larger air bubbles which can more easily escape, after which the method is preferably again performed at ambient pressure).

According to an important embodiment, the aqueous medium has a temperature of about 0°C.

At this temperature the ratio of the densities of plastics to be separated, such as polyethylene and polypropylene, is maximal.

According to an important embodiment, separate discharge-facilitating particles are present in the fluid medium.

The presence of facilitating particles may be of particular importance when the composition of the mixture varies. By placing a partition substantially in the middle of the layer of the facilitating particles, the achievement of an optimal separation may be ensured. The facilitating particles may be separated from a stream enriched with a particular type of particles by any suitable means, such as the use of magnetism if the facilitating particles are ferromagnetic. Of course, facilitating particles recovered will be fed back into the separation chamber.

In this manner the separation of two types of particles may be optimised. It is also conceivable that more layers of facilitating particles are formed between (for example three) different types of particles.

Preferably the facilitating particles are bulky particles having a density between the densities of the streams enriched in particular particles.

This embodiment is very advantageous when the particles to be separated are flakes. The bulky particles will experience an effective density of its surrounding determined by both the density of the fluid medium and the particles

present. The different shape of the particles to be separated on the one hand and the facilitating particles on the other, makes it very easy to separate the facilitating particles from a stream enriched in a particular type of particle. The bulky facilitating particles may have a largest size similar to that of the largest particles to be separated, but its thickness will be significantly more than that of the particles to be separated, such as at least five times more. Advantageously the bulky particles are, for example, approximately spherical particles, cylindrical particles or polygonal bodies such as cubes etc.

Preferably an element provided in the separation chamber is used as the barrier for restraining the particles in the separation chamber.

Such an element makes it easy to generate the up and down moving flow of fluid medium while causing a minimal disturbance of particle layers already partially separated.

Preferably the element for restraining the particles comprises passages for the passage of the fluid medium.

As such an element a sieve or grating is suitable, the openings of which will suitably, be smaller than the smallest particles of the mixture.

Preferably the element is at an angle with the horizontal, preferably at an angle between 2-45°, and more preferably between 5-30°, 5-20° being most preferred, such that the particles are transported away from the supply opening. This aids in the transport of the particle layers in the separation chamber.

The invention also relates to a device suitable for separating particles having a density lower than that of the fluid medium.

Such an apparatus is characterized in that the apparatus comprises a separation chamber having a supply opening for particles to be separated and an element provided above the supply opening for restraining said particles, which apparatus is further provided with means for moving a fluid medium up and down relative to the particles to be separated.

Using such an apparatus makes it possible to achieve

an efficient separation of the particles in a cheap and simple manner. The element and the means for moving the fluid medium up and down may be the same, that is a sieve (or screen).

Preferably the element comprises openings for the passage of a fluid medium.

Such an element may suitably be a sieve of grating, of which the openings will suitably, be smaller than the smallest particles of the mixture.

According to a preferred embodiment, the element is provided at an angle with the horizontal, preferably at an angle between 2-45°, more preferably between 5-30°, 5-20° being most preferred, such that the particles are transported away from the place where they are supplied.

The invention also relates to an apparatus suitable for separating particles having a density lower than that of a fluid medium.

This apparatus is characterized in that the apparatus comprises a separation chamber having a supply opening for the particles to be separated said supply opening extending in a substantially radial direction and an element is provided above the supply opening, said element comprising a multitude of openings allowing the passage of said particles, first means are provided to move the fluid medium up and down relative to the particles to be separated and second means are provided to rotate the element relative to fluid medium in the separation chamber.

In operation, the mixture of particles to be separated will be supplied below facilitating particles. The element and the fluid medium may be rotated at the same speed (and in the same direction), allowing a very simple separation operation. The particles with higher density which do not pass the barrier consisting of the facilitating particles may be removed from the separation chamber, for example together with the facilitating particles. The facilitating particles can be separated from the particles with higher density by any conventional method, such as separation by size, using magnetic fields etc.

According to an interesting embodiment, the apparatus comprises means for locally disturbing a mass comprising added particles not capable of passing through the openings of said element and particular particles separated from particles which have passed through said openings of said element.

Thus it is possible to use the element to separate the facilitating particles from the particles having higher density. The means may comprise a pipe provided with a slit or number of nozzles from which fluid medium is ejected.

The invention also relates to a specific method of separating particles in a fluid medium having a density higher than that of the particles to be separated, wherein an apparatus according to the invention is used, a mixture of particles to be separated is supplied below a layer of facilitating particles having a thickness which doesn't allow them to pass through the openings of the element, the fluid medium in the separation chamber is rotated relative to the element, the element is moved up and down to move the fluid medium relative to the particles to be separated, causing particles with lower density to pass through the facilitating particles and through the openings in said element to end up in fluid medium above said element from which the particles are discharged from the separation chamber, whereas the facilitating particles act as a barrier for and restrain the particles with higher density, which particles with higher density are discharged from the separation chamber in the fluid medium below said element.

Preferably, the fluid medium is rotated with respect to the wall of the separation chamber.

According to an alternative method of separating particles in a fluid medium having a density higher than that of the particles to be separated, an apparatus according to an alternative embodiment of the invention is used, a mixture of particles to be separated is supplied below a layer of facilitating particles having a thickness which doesn't allow them to pass through the openings of the element, the fluid medium in the separation chamber is rotated relative to the

element, the element is moved up and down to move the fluid medium relative to the particles to be separated, causing particles with lower density to pass through the facilitating particles and through the openings in said element to end up in a first section comprising fluid medium above said element from which first section the particles are discharged from the separation chamber, whereas the facilitating particles act as a barrier for and restrain the particles with higher density, the means for locally disturbing the mass of facilitating particles and restrained particles with higher density, allowing said particles with higher density to pass through the openings in said element to end up in a second section above the element separated from the first section and discharging a stream enriched in particles having a higher density from the separation chamber.

The present invention will now be illustrated with reference to a drawing and an exemplary embodiment wherein

Fig. 1 depicts a schematic representation of an apparatus according to the invention;

Figs. 2a - d each show a picture of four successive points in time during the separation of particles using the method according to the invention;

Fig. 3 depicts a first alternative schematic representation of an apparatus according to the invention; and

Fig. 4 depicts a second alternative schematic representation of an apparatus according to the invention.

The apparatus 1 shown in Fig. 1 possesses a chamber 2 provided with a supply opening 3 through which a mixture of particles to be separated can be supplied. Above the supply opening 3 a sieve 4 is mounted, the lowest part of the sieve 4 being adjacent to the supply opening 3. In operation, a fluid medium is present in separation chamber 2, which fluid can be moved up and down using a pump 5. For the discharge of separated particles two discharge openings 6, 7 are provided as well as a partition 8 for separating the particle layers. This partition 8 is preferably rotatable, making it easier to subject a mixture in which the ratio of the type of particles varies, to a separation.

It has been found that it is advantageous to increase the resistance with which the fluid medium may flow though the passages of the sieve 4. This may be achieved, for example, by putting a layer of pebbles on top of the sieve 4.

If necessary, the mixture of particles to be separated is first subjected to a separation according to particle size, but the method according to the present invention is, in case of flake-shaped particles to be separated, surprisingly insensitive to the diversity of particle size in the mixture.

According to a very interesting embodiment particles to facilitate/separate discharge of different particles are present. According to a first embodiment, these particles will facilitate the division into separate streams of layers comprising a particular type of particle resulting from the separation. A partition can be placed in the layer of facilitating particles. This is much easier than determining the border between two layers comprising different particles. According to a second embodiment, the use of facilitating particles makes it possible to use a barrier having openings allowing the passage of the particles to be separated. For example and as schematically depicted in Fig. 3, the openings in sieve section 4a do not allow for the passage of particles. The screen section 4b allows for the passage of lower-density particles (which are discharged from the separation chamber 2 through outlet 13 shown in fig. 4), whereas higher-density particles, which are not capable of penetrating the layer of facilitating particles, will pass through openings in sieve section 4c and are discharged from the separation chamber 2 through outlet 14 (shown in fig. 4).

The apparatus shown in fig. 4 (top view) comprises a circular screen 4 (shown in part) which retains facilitating particles having density chosen such that they end up between particles having a relative low density and particles having a relative high density. The mixture of particles to be separated is supplied in a substantially radial direction through a supply tube 9 having a slit-like supply opening 3 or a multitude of supply openings 3 distributed over a substantial

part of the length of the supply tube 9. Both the screen 4 and the fluid medium in the separation chamber 2 are rotated counter-clockwise. This may be accomplished using a water jet. According to an alternative embodiment, the rotating screen 4 causes the fluid medium to rotate. To avoid a detrimental effect because of turbulence near the wall of the separation chamber, the screen 4 may be provided with circumferential, downward extending wall (not shown, but similar to fig. 3 near supply opening 3), the wall having a height larger than the length of stroke during operation.

In operation, particles having a lower density will pass through the layer of facilitating particles and through openings in the screen 4. A stream comprising fluid medium and particles having a lower density may be discharged from the separation chamber 2 from above the screen 4. The facilitating particles act as a barrier for the particles having a relatively higher density. The latter particles may be removed from below the screen 4 together with (a part of) the facilitating particles. Any facilitating particles present in a stream enriched in particles having a higher density may be separated using any conventional means, and will be fed back into the separation chamber 2 below the screen 4.

Alternatively, the screen 4 may be used to separate the denser particles from the facilitating particles by disturbing the strata (facilitating particles and denser particles). This may be easily achieved using pipes 12 provided with nozzles which supply fluid medium to disturb the subtle balance in the strata, causing the denser particles to go through the screen 4. In this case, two separate sections 10, 11 are provided above the screen 4. Both sections 10, 11 may move up and down together with the screen, but do not rotate. The first section 10 is used to collect particles having a lower density, the second section 11 is used to collect particles having a higher density.

<u>Example 1</u>

A mixture was prepared of 0.8 kg HDPE (white: density 945 kg/m^3) and 0.2 kg PP (blue, density 900 kg/m^3). The

grain size of both types of plastic was 1.7 - 4 mm. The apparatus used had a separation chamber with a volume of 3.1 litre and a diameter of 19 cm. Water was used as the fluid medium. To separate, the water was moved up during 1 second and down during 3 seconds in an asymmetric sinusoidal manner. The length of stroke was 9 cm. The stationary screen had passages of 0.5 mm square, with 100 passages per cm^2.

Fig. 2 shows that despite the small difference in density a separation can be achieved very quickly. The pictures a - d were taken within a timespan of 2 min.

Example 2

In this experiment, an apparatus as depicted in fig. 3 was used having a sieve 4 made of bars providing slit-like openings (width 6 mm, length several cm). Facilitating particles were used having a density of 970 kg/ m^3, a length of 8-12 mm, a diameter of 8 mm and in an amount equivalent to two layers, to separate flakes of PP (density approximately 900 kg/ m^3) and HDPE (density approximately 950 kg/m^3). Conditions: frequency 10/minute; length of stroke: 45 mm; screen section 4a 300 mm, screen section 4b 50 mm. Screen width: 200 mm. Separation occurs in a period of 1-2 minutes. The PE obtained was almost pure (less than 1% PP). PP still comprised about 10% PE, which is still a significant improvement over the original 50/50.

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